

CONFIDENTIAL

TABLE OF CONTENTS

	<u>Page No.</u>
I. Introduction.	1
II. Technical Program	2
1. IF Amplifier Using Ceramic Trans-	
formers.	2
2. IF Amplifier With Miniaturized	
Crystal Filter	9
III. Manpower Requirements and Time Schedule . . .	12
IV. Facilities.	15
V. Identification of Key Technical Personnel . .	17

CONFIDENTIAL

-1-

I. Introduction

During the course of previous programs undertaken for the Contracting Agency, methods have been investigated whereby small IF amplifiers could be designed which would give superior performance. Various approaches have been taken including the miniaturization of conventional components and the development of new devices. As a result of the work which has been carried out on these programs, the problems which prevented satisfactory performance of the new techniques and devices have been defined. Developments in other areas have now provided solutions to many of these problems. The purpose of the proposed program is to design and construct two miniaturized IF amplifier packages. These amplifiers will represent the results of previous work in the areas of ceramic resonators for frequency selectivity and miniaturized crystal filters.

The two amplifiers will be designed in such a way that they may subsequently be evaluated on a comparative basis with regard to physical size, immunity to environmental changes, bandpass and center frequency stability, battery drain, spurious responses, power gain, etc.. One amplifier will be designed for a single conversion receiver and will utilize the design technique recently developed for miniaturized crystal filters, in order to achieve the desired bandpass characteristics. The second amplifier will be suitable for a double conversion receiver and will, where appropriate, utilize ceramic transformers for selectivity and interstage coupling. In order that the second amplifier may be compared

-2-

on an equable basis, the package will include both high and low IF amplifiers as well as local oscillator and mixer stages.

The target specifications for the two amplifier packages are as follows:

Input Frequency: 2.2 mc.

Output Frequency: 445 kc.

Overall Selectivity: To approximate the following:

Response (db)	Bandwidth (kc)
-3	5.0
-6	5.4
-10	6.2
-20	7.8
-40	11.2
-60	16.0

Overall Gain: 100 db.

Temperature: -40°C to +40°C.

These amplifiers will be packaged in as small a volume as the state of the art permits. It is anticipated that in the case of the crystal filter approach the size will be slightly over 2 cubic inches whereas the ceramic transformer version will be somewhat less than 2 cubic inches. The battery drain of the latter amplifier will, however, be slightly higher.

II. Technical Program

1. IF Amplifier Using Ceramic Transformers

The design of an IF amplifier may be based on one of two general methods. The first is that in which the overall selectivity is distributed

-3-

throughout the amplifier, usually in the form of tuned interstage coupling networks. The second approach relies upon the use of lumped selectivity with relatively broadly tuned coupling networks. In transistor circuitry, the latter method is frequently used, in order to minimize the changes in bandwidth and center frequency which result from variations of the transistor input and output impedances. The transistor impedances are subject to variation with temperature and operating point. The latter effect is particularly pronounced when AGC is applied to the transistor.

The IF amplifier to be constructed will employ ceramic transformers for interstage coupling. These devices will provide some degree of selectivity and impedance matching. The main selectivity will be determined by a lumped ceramic filter placed ahead of the first stage of the amplifier. Under the proposed program a complete IF strip will be constructed which would be suitable for inclusion in a double conversion receiver. In order that a comparison may be made with the crystal filter, single conversion IF strip, also to be constructed, the double conversion IF strip will consist of the following items:

- (a) High IF amplifier.
- (b) Mixer and crystal controlled local oscillator.
- (c) 455 kc ceramic lumped filter.
- (d) 455 kc ceramic transformer coupled IF amplifier.

Provision will be made for applying a gain control voltage so that comparisons may be made of bandwidth and center frequency stability.

-4-

The high IF amplifier, mixer and local oscillator will be, essentially, improved versions of those incorporated in the 3-30 mc. receiver which was recently delivered. Use will be made of the ferrite temperature stabilization techniques which were developed, in order to construct frequency selective networks which are physically extremely small. Ceramic resonators or transformers will not be used in the high IF amplifier because, with present modes of operation, their physical size at frequencies above about 1 mc. becomes too small to be practical. The overall size of the high IF amplifier, mixer and local oscillator will be less than one cubic inch.

(a) Ceramic Filter

Recent developments have resulted in ferroelectric ceramics which are suitable for use in bandpass filters operating in the frequency range from 40 kilocycles to 1 megacycle. The major advantage of a ceramic filter over a lumped constant parameter filter is a considerable size reduction.

Ceramic bandpass filters may be built by either of two techniques. The ferroelectric ceramic elements may be used either as two terminal resonators or as two terminal pair transformers. If the two terminal resonators are used as the basic elements, the filters are developed along lines similar to those used in quartz crystal filters. However, filters of small volume and fewer components can be made if the ferroelectric ceramic is used as a two terminal pair transformer. This latter approach is the one that will be discussed here.

-5-

A ceramic transformer consists of a rectangular bar of polycrystalline ferroelectric ceramic such as barium titanate which has been polarized so that it will exhibit piezoelectric coupling. Silver electrodes are fired on the ceramic bar and lead wires for electrical connections are attached to the electrodes prior to the polarization of the ceramic transformer. A typical ceramic transformer is shown in Figure 1. The direction of polarization of this ceramic transformer is along the length of the bar so that the ceramic transformer exhibits longitudinal mode vibrations. The input voltage excites mechanical vibrations of the ceramic transformer and a resultant output voltage is produced by piezoelectric coupling, providing the frequency of the exciting voltage is in the vicinity of the mechanical resonant frequency of the ceramic transformer. Hence a two terminal pair ceramic transformer provides frequency selectivity through mechanical resonance.

The equivalent circuit of this ceramic transformer, which is valid around the mechanical resonant frequency, is also shown in Figure 1. From this equivalent circuit it can be seen that the frequency response characteristic of a ceramic transformer is essentially that of a series resonant circuit.

Several of these ceramic transformers are connected in cascade to provide a composite filter meeting the bandwidth, shape factor and other specifications. Since the coupling between individual ceramic transformers is electrical rather than mechanical as in most other electromechanical filters, it is possible to interconnect and arrange

5A

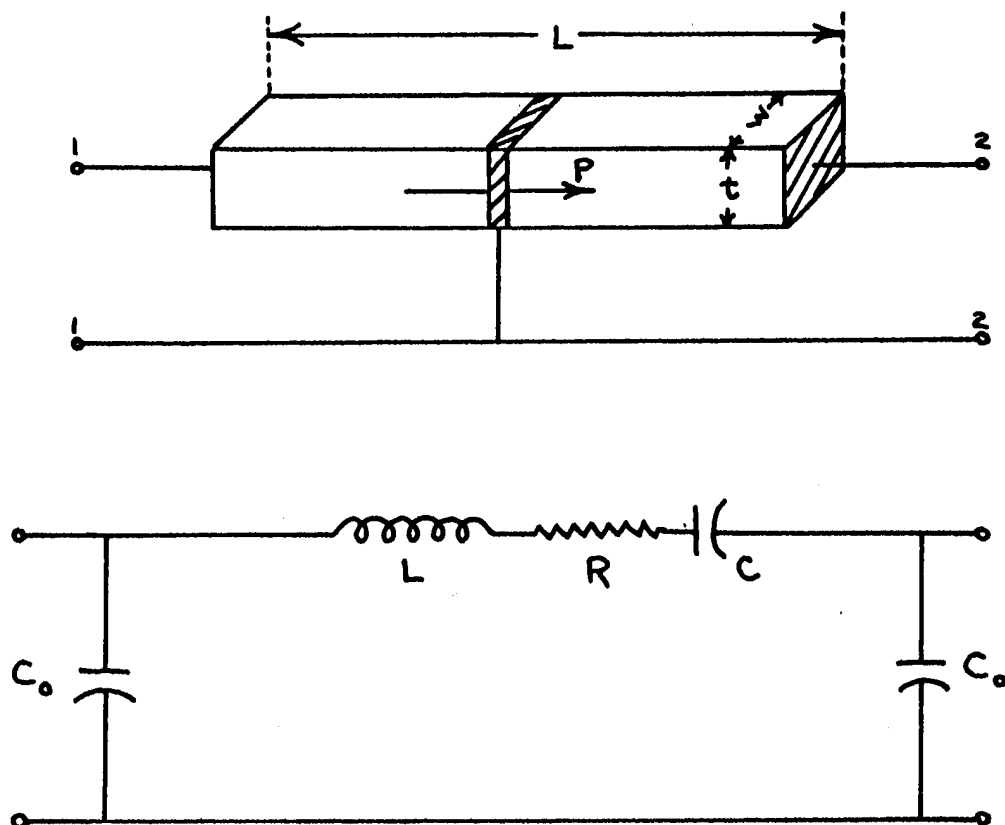


Figure 1
Long Thin Bar Ceramic Ring Transformer

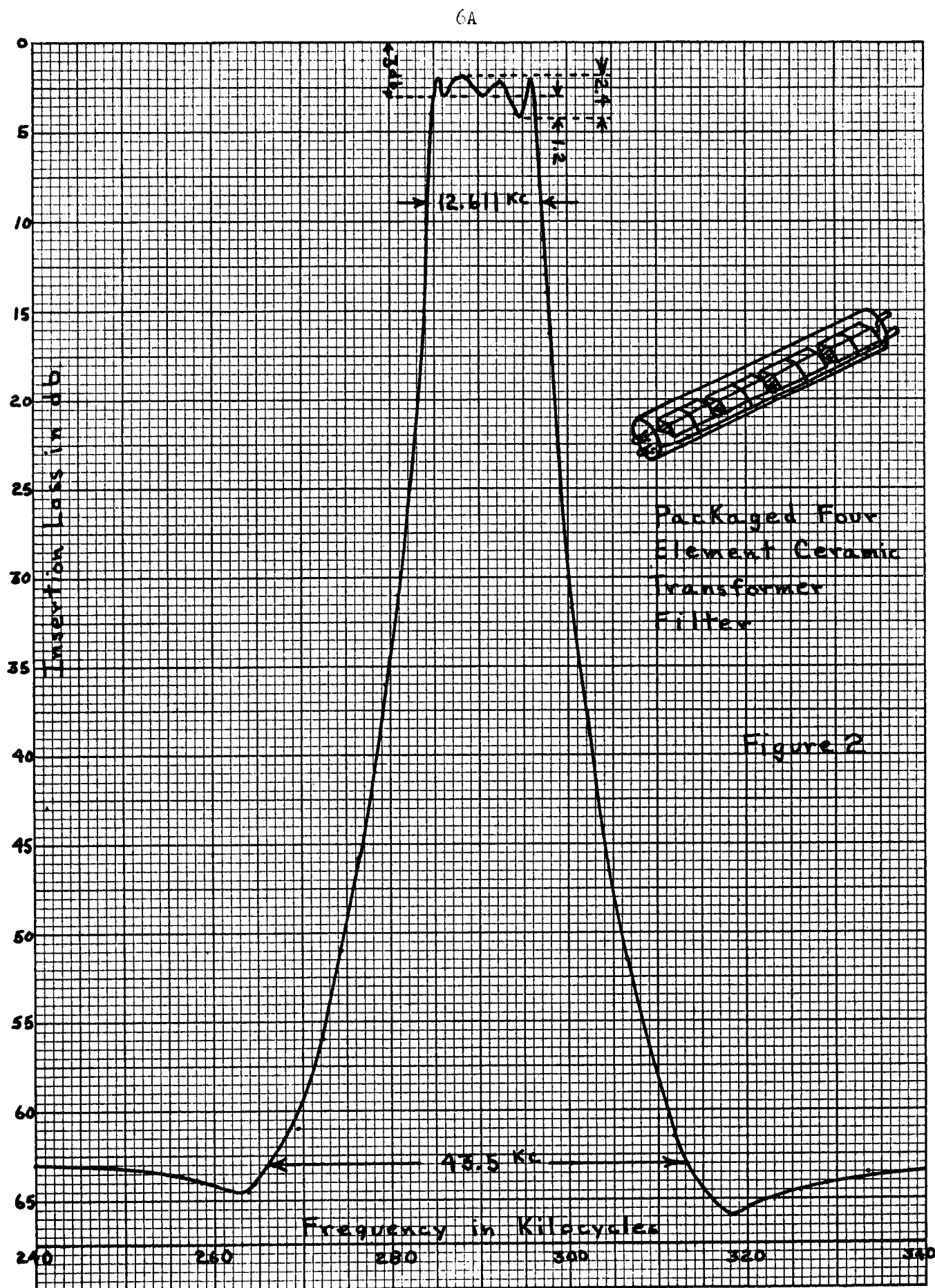
-6-

these ceramic transformers in such a way as to yield not only a compact filter with a very small volume but also to arrange the configuration of the filter in such a manner as to minimize waste space in the overall circuit.

Ceramic transformer filters are designed on an image parameter basis using the equivalent circuit shown in Figure 1. However, the inductances and capacitances of the equivalent circuit have limitations upon their values which are imposed by the ceramic transformer geometry and the ceramic material constants. Basically the desired operating frequency controls the length of the ceramic transformer since the ceramic transformer length is such that it is one-half wavelength long at the velocity of sonic propagation in the ceramic material at the desired frequency. The transverse dimensions of the ceramic transformer control the values of the capacitors, C_o , in Figure 1 and hence the impedance levels of the ceramic transformer. However, there is a limit to how large the width and thickness can be made. If these transverse dimensions approach a quarter wavelength there is a tendency for spurious modes of vibration to be introduced close to the fundamental mode frequency.

Figure 2 shows the frequency response characteristic of a four element ceramic transformer filter of the type discussed above. This particular filter was designed to operate at 290 kilocycles and was packaged in a cylindrical tube 2 inches long and 0.4 inches in diameter and had a volume of 0.3 cubic inches.

A four element 455 kilocycle ceramic transformer filter would have the same relative response on a percentage basis as that shown in



-7-

Figure 2 for the four element 290 kilocycle ceramic transformer filter. However, since a fundamental mode ceramic transformer is less than 200 mils in length for operation at 455 kilocycles, a four element cylindrical tube design of the same nature as that shown in Figure 2 for the 290 kilocycle ceramic transformer filter would be approximately 1 inch long and have a volume of less than 0.1 cubic inch. Furthermore, as pointed out above, other packaging arrangements could be used if some other form would contribute to a more effective utilization of the overall receiver volume.

The four element 455 kilocycle ceramic transformer filter proposed here appears to be the simplest filter that will meet the tentative specifications for this project. Other techniques are available for tailoring ceramic transformer filters to a specific application. The shape factor and bandwidth of the filter response can be modified by changing either the number or type of ceramic transformers used in the filter. Techniques for placing peaks of attenuation at certain frequencies either above or below the passband are available as well as techniques for spurious mode suppression and impedance level transformation.

(b) 455 kc IF Amplifier Stages

The interstage coupling networks to be used in the 455 kc IF amplifier will consist of ceramic transformers of basically the same configuration as that used for the individual sections of the lumped filter described in the previous section. The transformers in the lumped filter

-8-

will be designed to have a 1:1 transformation ratio, whereas those used for interstage coupling will have a step down ratio in order to match the output impedance of the preceding stage to the input impedance of the next transistor. The ratio of transformation is determined by the location of the ring electrode around the bar. The closer the ring is placed to one end of the bar, the greater the transformation ratio. In practice this ratio can not be made as high as might be desired because the ring electrode has a finite width. Consequently, when the ring electrode is placed close to one of the end electrodes, the field is considerably different from the orthogonal field which would exist between two plane electrodes.

The ceramic transformer does not provide a d.c. path for biasing the transistors. Parallel feeding is therefore necessary, either by means of a choke or a resistor. In the interests of small size, a resistor is preferable. A compromise has to be made between loss due to the shunting effect of the resistor and excessive battery voltage requirements.

By the use of miniature transistors in the three stage amplifier, it is anticipated that the volume of the IF amplifier will not exceed 0.5 cubic inches. In order to achieve this small size, it is proposed to construct the amplifier, using polyethylene as the medium for holding the components in place. In this way, a three dimensional arrangement of components is possible without relying on component leads for mechanical support. For the ceramic transformers themselves, this method of assembly is particularly advantageous. The rectangular transformers will be mounted in circular holes so that the contact between the ceramic transformer

-9-

and the polystyrene will be at a minimum. This is necessary since any constraints on the ceramic transformer will tend to damp the resonant vibrations and cause a decrease in output. To reduce motion of the transformer due to external shocks and vibrations, which might break the transformer leads, styrofoam plugs will be inserted in the bar hole after the transformer has been mounted. While these styrofoam plugs will tend to keep the bar from shifting, they will not be so tight that they will constrain the resonant vibrations of the ceramic transformer, styrofoam being very compliant.

From the point of view of electrical performance, it is anticipated that a gain of 80 db can be obtained with a three stage amplifier of the type described. An effort will be made to keep the battery drain to an absolute minimum. Using the ceramic material recently developed by the Clevite Company, it is not anticipated that changes in temperature over the range from -40°C to $+40^{\circ}\text{C}$ will produce any significant change in the bandpass or center frequency characteristics of the ceramic transformers. Precautions will be taken to ensure that changes in transistor characteristics over this temperature range will not cause a deterioration in amplifier performance.

2. IF Amplifier With Miniaturized Crystal Filter

During the recently concluded program a miniaturized crystal filter was developed. This filter was not included in the 3-30 mc receiver since the design of the latter had to be frozen before the design of the crystal

-10-

filter was sufficiently advanced. The object of developing this filter was to make feasible the design of a single conversion receiver meeting rigid image rejection specifications. Crystal filters for this purpose have been commercially available for some time but their physical dimensions have not made them usable in ultraminiature receivers.

The purpose of the proposed program is to construct an IF amplifier suitable for use in a single conversion receiver, which may be evaluated in terms of physical size, electrical performance, etc.. By arranging for the input and output conditions to be the same as those for the ceramic transformer IF package, a direct comparison may be made between the two amplifiers.

At the conclusion of the previous program the design techniques which had been developed for a miniaturized crystal filter were demonstrated by the construction of a small filter. The performance of this filter came close to the design objectives. The overall physical size was appreciably smaller than any commercially available filter of comparable performance despite the fact that the crystals themselves were standard units obtained commercially. Under the proposed program a further reduction in size with a possible improvement in characteristics will be obtained by utilizing the facilities of [REDACTED]

25X1

[REDACTED] to fabricate crystal wafers specifically for this filter and to incorporate them in a miniaturized package including input and output transformers.

25X1

-11-

As a basis of comparison, a typical commercially available filter coming close to the requirements of this application measures $1 \frac{47}{64}$ x $1 \frac{5}{16}$ x $2 \frac{9}{16}$ or approximately 5.83 cubic inches. A filter with comparable performance constructed with standard crystals, using the technique developed during the previous program, results in a reduction in volume to 40% or 2.35 cubic inches. By the use of specially fabricated crystal wafers a volume of approximately 1 cubic inch or slightly less, depending upon the shape factor, is possible. The filter to be constructed under the proposed program will, if found satisfactory by the customer, be suitably packaged for subsequent production.

The IF amplifier associated with the crystal filter will consist of a series of broadly tuned cascaded transistor stages. The interstage coupling circuits will have fixed tuning thereby eliminating the necessity for any alignment. Provision will be made for controlling the gain of the amplifier electrically. The environmental temperature range of the amplifier will be from -40°C to +40°C.

-12-

III. Manpower Requirements and Time Schedule

The manpower effort required to implement the program described above is estimated to be as follows:

	<u>Man Weeks</u>
<u>Single Conversion IF Amplifier</u>	
Engineering	8
Technician	4
<u>Crystal Filter Packaging</u>	
Engineering	17
Technician	9
<u>High and Low IF Amplifier, Mixer and Local Oscillator</u>	
Engineering	17
Technician	7
<u>Ceramic Transformer Filter</u>	
Engineering	17
Technician	6
Total: Engineering	59
Technician	26

The proposed time schedule for implementing this program, which will be initiated on July 1, 1959 and completed by May 31, 1960 is as follows:

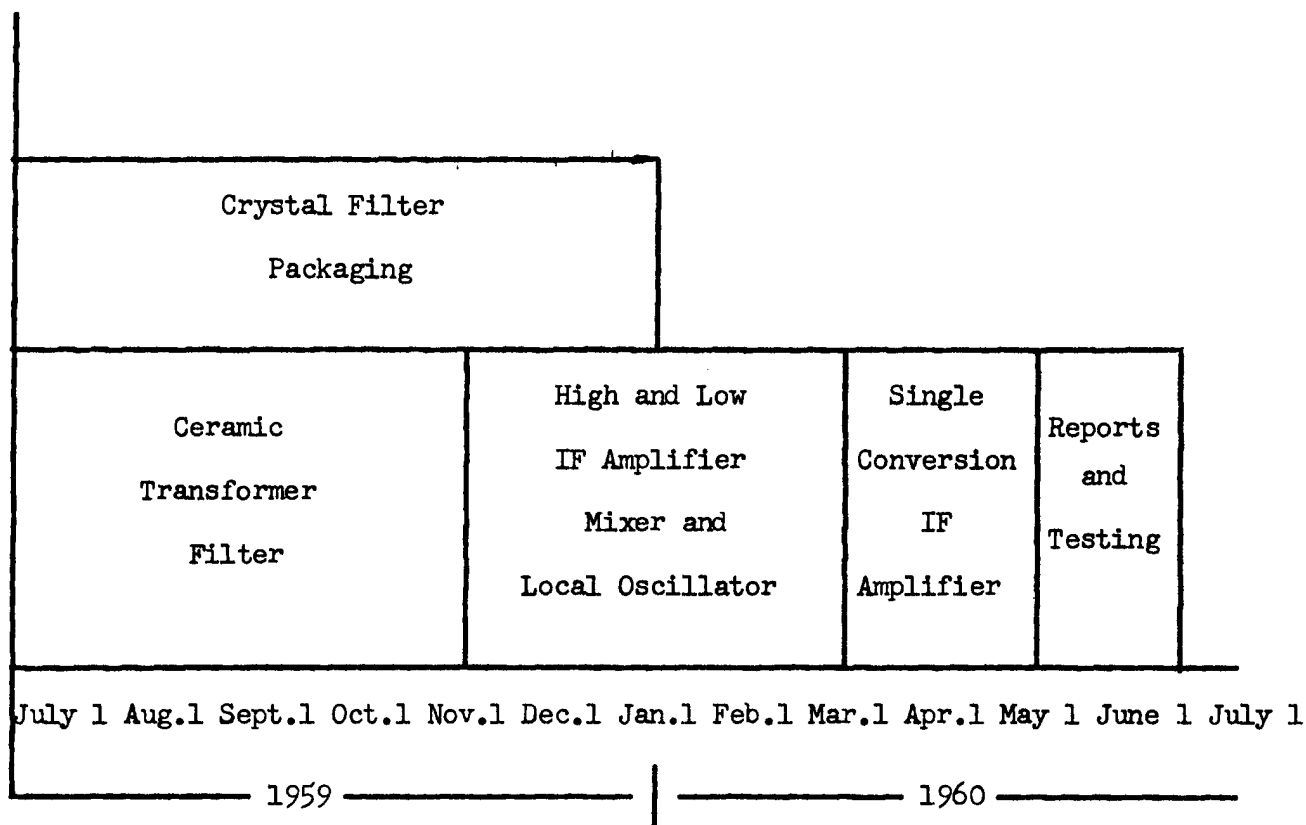
Crystal Filter Packaging	July 1, 1959 - Dec. 31, 1959
Single Conversion IF Amplifier	Mar. 1, 1960 - April 30, 1960
Ceramic Transformer Filter	July 1, 1959 - Oct. 31, 1959
High and Low IF Amplifier, Mixer and Local Oscillator	Nov. 1, 1959 - Feb. 29, 1960

-13-

The above dates are given on the basis that the contract will be signed prior to July 1, 1959. If the contract is not signed by this time, all dates will be postponed by an amount equal to the delay in signing after July 1, 1959.

A chart of engineering manpower is shown on the following page.

-14-

Engineering and Technician ManpowerSchedule

Page Denied

Next 5 Page(s) In Document Denied